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MATHEMATICAL PROGRAMMING METHODS FOR LOGISTICS PLANNING.(U)
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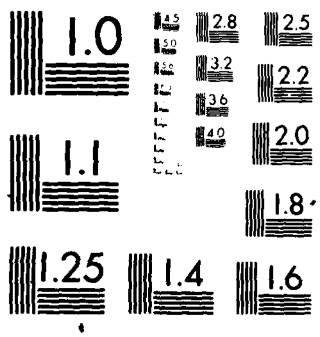

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The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This project was concerned with the application of mathematical programming models and techniques to logistics planning problems. Basic research was performed on a new approach, called inverse optimization, to the parametric analysis of mixed integer programming models. The approach was implemented and tested for the capacitated plant location problem. Basic research was also performed on three other logistics planning models with cyclic structures; namely, lot-size problems when demand and costs are cyclic, vehicle routing and cyclic staffing. A final research effort, partially suggested by the contract, was the construction and optimization, using decomposition methods, of a model of the U.S. coal supply and demand markets.

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FINAL REPORT TO ARO

This final report covers the contract period, January 20, 1980 through January 19, 1981. Professor Jeremy F. Shapiro, Co-Director of the Operations Research Center, was Co-Principal Investigator during the contract period. Joining him as Co-Principal Investigator was Professor Stephen C. Graves of the Alfred P. Sloan School of Management.

STATEMENT OF THE PROBLEM STUDIED

This project was concerned with the application of mathematical programming models and techniques to logistics planning problems. Basic research was performed on a new approach, called inverse optimization, to the parametric analysis of mixed integer programming models. The approach was implemented and tested for the capacitated plant location problem. Basic research was also performed on three other logistics planning models with cyclic structures; namely, lot-size problems when demand and costs are cyclic, vehicle routing and cyclic staffing. A final research effort, partially suggested by the contract, was the construction and optimization, using decomposition methods, of a model of the U.S. coal supply and demand markets.

Journal Articles

Shapiro, J.F. and D.E. White, "Decomposition and Integration of Coal Supply and Demand Models," (submitted to Operations Research).

Bitran, G.R., V. Chandru, D.E. Sempolinski, and J.F. Shapiro, "Inverse Optimization: An Application to the Capacitated Plant Location Problem," (to appear in Management Science).

Working Papers

Graves, S.C. and J.B. Orlin, "The Infinite-Horizon Dynamic Lot-Size Problem with Cyclic Demand and Costs," Working Paper OR 101-80, M.I.T. Operations Research Center, August 1980.

Orlin, J.B., "Minimizing the Number of Vehicles to Meet a Fixed Periodic Schedule: An Application to Periodic Posets," Working Paper OR 102-80, M.I.T. Operations Research Center, October 1980.

Karp, R.M. and J.B. Orlin, "Parametric Shortest Path Algorithms with an Application to Cyclic Staffing," Working Paper OR 103-80, M.I.T. Operations Research Center, October 1980.

SCIENTIFIC PERSONNEL supported entirely or in part by ARO during the contract period:

Vijaya Chandru
February 1, 1980 - May 31, 1980
September 1, 1980 - January 15, 1981

Professor Stephen C. Graves
September 1, 1980 - December 31, 1980

Judith Kramer
September 1, 1980 - January 15, 1981

Professor Jeremy F. Shapiro
September 1, 1980 - January 15, 1981

DEGREES AWARDED during the report period supported (in part) by ARO:

White, D.E., "The Application of Mathematical Programming Decomposition Techniques to the Integration of a Large Scale Coal Energy Model," PhD in Civil Engineering, February 1980.

Sempolinski, D.E., "Inverse Optimization Applied to Fixed Charge Models," PhD in Operations Research, February 1981.

ABSTRACTS OF RESEARCH FINDINGS supported entirely or in part by ARO during the contract period and cited in this final report are appended.

Decomposition and Integration of Coal Supply

and Demand Models*

by

Jeremy F. Shapiro and David E. White

Massachusetts Institute of Technology

August, 1980

*This research was supported in part by grants from the Center for Energy Policy Research at M.I.T. and by the U.S. Army Research Office (Durham) under Contract No. DAG29-80-C-0061. The authors wish to express their gratitude to Martin Zimmerman for his many helpful suggestions and for providing much of the data for our research.

Decomposition and Integration of Cual Supply and Demand Models

by

Jeremy F. Shapiro and David E. White

ABSTRACT

Several large scale mathematical programming models have been proposed and implemented in recent years to study the anticipated expansion of coal production and utilization in the U.S. This paper reports on the application of mathematical programming decomposition methods to the construction and optimization of these models. A hybrid decomposition algorithm that is resource-directive on the supply side and price-directive on the demand side was observed to have fast and stable convergence behavior. Results addressing specific coal policy questions are also reported using the decomposition approach.

INVERSE OPTIMIZATION: AN APPLICATION TO

THE CAPACITATED PLANT LOCATION PROBLEM

by

Gabriel R. Bitran, Vijaya Chandru,

Dorothy E. Sempolinski and Jeremy F. Shapiro

September 1979

revised
June 1980
December 1980

Research supported, in part, by the National Science Foundation under Grant No. MCS77-24654 and by the Army Research Office under Contract No. DAAG29-80-C-0061.

Abstract

Inverse optimization refers to the fact that each time a Lagrangean derived from a given mathematical programming problem is solved, it produces an optimal solution to some problem with an appropriate right hand side. This paper reports on the application of inverse optimization to the capacitated plant location problem including the study of implied mappings of dual variables into the space of demand vectors. A new parametric method based on inverse optimization and subgradient optimization is also presented and computational experience with it is reported.

THE INFINITE-HORIZON DYNAMIC LOT-SIZE PROBLEM WITH CYCLIC DEMAND AND COSTS

by

Stephen C. Graves

and

James B. Orlin

OR 101-80 August 1980

Research supported in part by the U.S. Army Research Office under Contract No. DAAG29-80-C-0061.

0. INTRODUCTION

In this paper we consider an infinite-horizon, dynamic lot-size problem with cyclic demand and costs. This problem is a natural extension of the finite-horizon problem first studied by Wagner and Whitin [10]. After formulating the infinite-horizon problem, we interpret the problem as a minimal cost-to-time ratio circuit problem [2]. With this interpretation we establish directly that an optimal policy is periodic and specify an efficient algorithm for finding the optimal policy. Finally we indicate how these results pertain to simple extensions of the problem, first allowing backorders and then allowing a discounted cost criterion.

MINIMIZING THE NUMBER OF VEHICLES
TO MEET A FIXED PERIODIC SCHEDULE: AN
APPLICATION OF PERIODIC POSETS

by

James B. Orlin

OR 102-80 October 1980

Research supported, in part, by the U.S. Army Research Office under Contract No. DAAG29-80-C-0061.

ABSTRACT

In this paper we consider countably infinite partially ordered sets (posets) in which the order relations occur periodically. We show that the problem of determining the minimum number of chains (completely ordered subsets) needed to cover all of the elements may be solved efficiently as a finite network flow problem. A special case of the chain-cover problem for periodic posets is the problem of minimizing the number of individuals to meet a fixed periodically repeating set of tasks with set-up times between tasks. For example, if we interpret tasks as flights and individuals as airplanes, the resulting problem is to minimize the number of airplanes needed to fly a fixed daily-repeating schedule of flights, where deadheading between airports is allowed.

PARAMETRIC SHORTEST PATH ALGORITHMS WITH AN APPLICATION TO CYCLIC STAFFING

by

Richard M. Karp

and

James B. Orlin

OR 103-80 October 1980

Research supported, in part, by the U.S. Army Research Office under Contract No. DAAG29-80-C-0061.

Parametric Shortest Path Algorithms with an Application to Cyclic Staffing

by

Richard M. Karp and James B. Orlin

Abstract

Let $G = (V,E)$ be a digraph with n vertices including a special vertex s. Let $E' \subseteq E$ be a designated subset of edges. For each $e \in E$ there is an associated real number $f_1(e)$. Furthermore, let

$$f_2(e) = \begin{cases} 1 & \text{if } e \in E' \\ 0 & \text{if } e \in E-E' . \end{cases}$$

The <u>length</u> of edge e is $f_1(e) - \lambda f_2(e)$, where λ is a parameter that takes on real values. Thus the length varies additively in λ for each edge of E'.

We shall present two algorithms for computing the shortest path from s to each vertex $v \in V$ parametrically in the parameter λ, with respective running times $O(n^3)$ and $O(n|E| \log n)$. For dense digraphs the running time of the former algorithm is comparable to the fastest (non-parametric) shortest path algorithm known.

This work generalizes the results of Karp [2] concerning the minimum cycle mean of a digraph, which reduces to the case that $E' = E$. Furthermore, the second parametric algorithm may be used in conjunction with a transformation given by Bartholdi, Orlin, and Ratliff [1] to give an $O(n^2 \log n)$ algorithm for the cyclic staffing problem.

THE APPLICATION OF MATHEMATICAL PROGRAMMING DECOMPOSITION TECHNIQUES TO THE INTEGRATION OF A LARGE SCALE COAL ENERGY MODEL

by

DAVID EDWIN WHITE

B.S. The University of Akron (1966)

M.S. Case-Western Reserve University (1968)

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

January 1980

The Application of Math Programming Decomposition Techniques to the Integration of a Large Scale Coal Energy Model

By David E. White

ABSTRACT

This paper explores the applicability of mathematical programming techniques for the integration on large scale energy models, and describes their application to the integration of a dynamic, large scale, partially nonlinear, coal supply and demand model. First, the components of a generic coal model are described and several currently available coal models are reviewed. Then a variety of applicable math programming solution techniques, including both price and resource directed decompositions, are discussed. The next section describes the creation of an integrated coal analysis model (ICAM) and the results of testing and evaluating a variety of decomposition / integration techniques. The final section includes an analysis of some of the model's policy implications, a critique of the model itself, and some suggestions for future studies and model extensions.

INVERSE OPTIMIZATION APPLIED TO FIXED CHARGE MODELS

by

DOROTHY ELLIOTT SEMPOLINSKI

Sc.B., Brown University
(1975)

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF

DOCTOR OF PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

December 1980

Signature of Author Dorothy E. Sempolinski
Operations Research Center
December 18, 1980

Certified by Jeremy F. Shapiro
Jeremy F. Shapiro
Thesis Supervisor

Accepted by ______________________________
Chairman, Departmental Graduate Committee

INVERSE OPTIMIZATION APPLIED TO FIXED CHARGE MODELS

by

DOROTHY ELLIOTT SEMPOLINSKI

Submitted to the Operations Research Center on December 18, 1980 in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Operations Research

ABSTRACT

The use of Lagrangean techniques in parametric analysis for fixed charge integer programming problems is explored using the properties of inverse optimization. In inverse optimization, the solution to a Lagrangean relaxation of a problem produces an optimal solution to a different problem: the problem for the particular right hand side which that solution satisfies. The inverse optimization approach is useful when constraints are "soft" or subject to uncertainty. The set of solutions provided by solving the Lagrangean relaxation using various choices of the dual vector can be expanded by strenghtening the Lagrangean problem. This is done by including the constraints of a group theoretic aggregation of the demand constraints.

The use of the group theoretic constraint to strengthen the Lagrangean problem produces a fixed charge group optimization problem. An algorithm to solve this class of problems is presented and computational experience with it is reported. The algorithm produces solutions for each group right hand side, and inverse optimization provides that these solutions are optimal in the original problem for right hand sides that they satisfy. This technique is extended by the use of approximation techniques for which computational experience is also reported.

Thesis Supervisor: Dr. Jeremy F. Shapiro
Professor of Operations Research and Management